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A PREFABRICATED TOWER FOUNDATION COMPRISING EQUIPMENT SHELTERS AND A METHOD FOR ITS DEPLOYMENT ON SITE

FIELD OF THE INVENTION

The present invention relates in general to foundations for towers and, in particular, to foundations for towers in telecommunication sites that are commonly used by a plurality of networks or users, each network or user requiring its own equipment shelter.

BACKGROUND OF THE INVENTION

Many types of wireless telecom networks, and especially cellular telephone networks or the like, require a large number of remote, unmanned sites.

In areas where no buildings, or only very low-rise buildings exist, such sites are normally located on bare ground, and are usually referred to as "Greenfield Sites". A Greenfield site employs a tower which supports various antennae at required heights above the ground, and in most cases also at least one shelter, which is usually a prefabricated small room serving as an enclosure for the indoor electronic equipment. When the Greenfield site serves more than one network, either a plurality of shelters or a single larger shelter may be used. In such shared sites, the facility of housing each network's equipment in a separately accessible individual room contemplates an operational and security advantage, as each operator may independently maintain and exercise its own access control procedures.

The construction of a new Greenfield site in compliance with the law requires, in most if not all countries, the prior obtainment of a building permit.

In recent years, as the number of various network operators in each country, and consequently the number and density of Greenfield sites, have been constantly increasing – the obtainment of building permits for new Greenfield sites serving a single network has become increasingly difficult, especially in the more developed countries, where environmental aspects have become an increasingly important consideration. The authorities tend to encourage network operators to

share amongst themselves the use of common new sites, and at the same time to build sites which present minimal possible disturbance to the environment, by making (amongst others measures) most efficient use of ground space.

At the same time, new wireless telecom networks tend increasingly to be built under fast roll-out constraints. Consequently, solutions which employ prefabricated elements instead of cast-on-site concrete elements, thus enabling more rapid construction in almost any weather condition, contemplate clear advantages to network roll-out managers.

An additional important aspect is the budgetary one: in the vast majority of Greenfield sites built to date, or even those being presently built, the tower foundation and the equipment shelter (or shelters) are function-wise totally separated from each other. A solution which makes a multi-functional use of the same elements (i.e. the shelters) has therefore the potential of significant cost savings, compared to the "conventional" solutions described above.

Accordingly, there is a felt need for, and an expected welcoming acceptance of, a rapidly deployable foundation for the tower in Greenfield telecom sites serving a plurality of networks or users, comprising a plurality of prefabricated concrete equipment shelters coupled together, thus forming a suitable foundation for the tower, and altogether consuming minimal ground-space.

PRIOR ART PUBLICATIONS

Numerous patents, patent applications and other prior art publications relate to antenna towers or the like, foundations for the same, and to equipment shelters or other type enclosures for electronic equipment, meant to be located near the base of a tower.

The following publications are believed to be the most relevant fore reference as prior art herein:

Disclosed in International Patent Application No. PCT/BR98/00029 to BITTENCOURT DE MIRA is a shelter for telecommunications equipment, particularly suitable for housing equipment utilized in cell phone systems and other telecommunications systems, this shelter being positioned in the internal region of a telecommunications tower, and having a cross section analogous to that of the

tower. In addition, the shelter is divided into at least two floors. There is also disclosed a telecommunications tower, particularly utilizable in cell phone systems, which comprises a shelter positioned in its internal region.

Disclosed in International Patent Application No. PCT/GB00/04846 to SMITH is a foundation comprising at least one prefabricated foundation element.

Disclosed in International Patent Application No. PCT/IL01/00174 to SILBER is a foundation for a tower, which is formed of a plurality of prefabricated slabs coupled together so as to function as a monolithic foundation.

Disclosed in U.S. Patent No. 6,351,250 to GILLEN is an antenna tower and support apparatus, which includes a foundation and a building mounted on the foundation, the building including a plurality of vertically spaced apart building sections (preferably two, three or more), a bottom and a top. A tower is supported upon the top of the building. A plurality of antenna are attached at multiple elevational positions. Each building section has a security area that is separate from the security area of the other building sections. A plurality of antenna portals are provided at least one on each building section. A plurality of antenna cables are provided, each cable extending from an antenna to a security area of a building section via an antenna portal, wherein each security area has at least one antenna cable that extends to it. Each security area has telecommunications equipment that is connected to one of the antenna cables.

Disclosed in U.S. Patent Application Publication No. 2002/0023394 to McGINNIS is an easily-constructed foundation for an antenna support tower, that requires no fabricated support surface at the installation site. The foundation is a radial array of prefabricated buildings connected near their inner corners to each other. In a first embodiment, one leg of a multi-legged tower rests on each building, the buildings transferring forces from the tower to the support surface below the buildings. In a second embodiment, a tapered monopole tower is located in the center of the array of buildings. The monopole tower may rest on a prepared surface or may be supported above the support surface. Support structures, each having a central ring and radially extending arms, are attached at the building connection points, one support structure above the other. The monopole tower is positioned within the central ring, transferring lateral loads through the ring and

arms to the buildings, negating the need for a moment base.

The shelter to BITTENCOURT DE MIRA is indeed designed to facilitate space-efficient installation of a telecommunication site, but it has no role whatsoever as a foundation to the tower or any other structural role.

The foundation to SMITH may indeed consist of a plurality of prefabricated foundation elements, but these elements are all rather small, and designed to support altogether not more than one equipment shelter.

The foundation to SILBER indeed comprises a plurality of prefabricated concrete elements, but these elements are flat slabs, and the connection there between is made substantially vertically, whereas the connection between the prefabricated shelters in the present invention is made substantially horizontally. Furthermore, there is no mention whatsoever to equipment shelters.

The antenna tower and support apparatus to GILLEN is employing vertically spaced apart building sections (i.e. shelters) while in the present invention the equipment shelters are spaced apart horizontally. Furthermore, the antenna tower and support apparatus to GILLEN require a separate, conventionally built foundation, while in the present invention the coupled shelters themselves serve essentially also as a foundation for the tower.

The foundation to McGINNIS is indeed the publication which is at shortest distance to the present invention, as there is also a plurality of equipment shelters spaced apart horizontally, connected altogether and suited to serve as a foundation for a tower. Nevertheless, the system used in the present invention for coupling every two adjacent shelters is totally different than that disclosed by McGINNIS, not only in detail but in the essential basic concept: in the foundation to McGINNIS the shelters are connected to each other only in their corners, while in the present invention the shelters abut each other, and are coupled to each other, through substantial wall surfaces. This provides a much stronger structural bonding between the shelters, and indeed facilitates their functioning altogether as a monolithic foundation. Furthermore, McGINNIS envisions only radially symmetrical layouts of substantially rectangular identical shelters, which therefore can contact each other only at their inner corners, while the present invention envisions numerous possible layouts of various shape shelters, either symmetrical or un-

symmetrical. Even when utilizing four identical rectangular shelters according to the present invention, these shelters would not be arranged radially, but rather in a much more compact arrangement, as disclosed in the preferred embodiment herein. Owing to the said layout advantage, the foundation constructed according to the present invention would consume a much smaller ground space than a similar foundation constructed according to McGINNIS, and will also have a much neater appearance: a smooth square plan contour instead of a cross-like plan contour. Finally, the present invention also features an optional foundation enhancement possibility, which is not envisioned at all by McGINNIS.

SUMMARY OF THE INVENTION

It is an aim of the present invention to provide an efficient overall solution for a telecommunication site or the like, based on the ground and employing a tower, which is utilized by a plurality of networks or users. The efficiency of the solution provided by the present invention results from its basic concept, of making a multi-functional use of a plurality of prefabricated concrete equipment shelters.

There is provided, therefore, in accordance with a preferred embodiment of the present invention, a foundation for a tower, comprising a plurality of prefabricated concrete shelters, each suitable for housing indoor equipment of a telecom network or the like, said shelters being arranged on site such that every shelter is abutting and coupled to at least one other adjacent shelter, such that a substantially vertical surface of contact exists there between, across which the means of said coupling is transversely effected, resultantly all said shelters are mechanically attached together and function as a monolithic foundation.

According to another preferred embodiment of the present invention, each of said shelters includes certain apparatus for anchoring part of tower-base, located on its roof, such that said anchoring apparatus of the entirely assembled foundation is geometrically fit and mechanically adequate to receive the base of said tower, either directly or through an interfacing tower-base structure.

There is also provided, in accordance with a preferred embodiment of the present invention, a method for constructing a foundation for a tower, said method primarily including:

Preparing the prefabricated components of said foundation, as described above;

Executing site preparation works in designated site area, so as to form a planar and horizontal adequate support surface for the foundation, moderately higher than the surrounding ground level;

Placing said prefabricated concrete shelters in their final designated positions in a sequential order, and effecting and tightening said means of transversely coupling the shelters in the same sequential order.

In order to facilitate utilization of the present invention even when the overturning loads effected by the tower, due to its height and wind-drag exposure, exceed the overturning resistance capacity of the basic foundation assembly of shelters, there is further provided, in accordance with an alternative embodiment of the present invention, a foundation enhancement assembly, placed underneath the assembly of said shelters, the two assemblies being fastened to each other by appropriate means of vertical fastening, said foundation enhancement assembly comprising.

A plurality of equi-high prefabricated concrete foundation elements, each having the shape of a box open at its top, said foundation elements being arranged on site such that every foundation element is abutting and coupled to at least one other adjacent foundation element, such that a substantially vertical surface of contact exists there between, across which the means of said coupling is transversely effected, resultantly all said foundation elements are mechanically attached together and function as a monolithic foundation.

According to yet another preferred embodiment of the present invention, said foundation enhancement assembly further includes an outwardly horizontal projection of its floor from its perimeter walls, all along its perimeter or along any part thereof, so as to increase the contact area between the bottom surface of said foundation enhancement assembly and the underlying supporting surface.

There is also provided, in accordance with another embodiment of the present invention, which may be effected in conjunction with the utilization of said foundation enhancement assembly, a method for constructing said foundation,

including:

Preparing the prefabricated components of said foundation, including said shelters and said foundation elements, as described above;

Executing site preparation works in designated site area, including excavation, so as to form a planar and horizontal adequate support surface for the foundation, at a depth below the surrounding ground level substantially equal to the height of said foundation enhancement assembly;

Placing said prefabricated foundation elements in their final designated positions in a sequential order, and effecting and tightening said means of transversely coupling the foundation elements in the same sequential order;

Backfilling and compacting the excavation around the placed and coupled foundation elements, preferably in individual layers;

Filling up the entire capacity within each of said foundation elements, as well as (if applicable) of the cavity encircled thereby, with local soil or with imported soil or granular material or sand;

Placing said prefabricated shelters in their final designated positions on top of said foundation elements in a sequential order, effecting and tightening said means of transversely coupling the shelters to each other, and effecting and tightening said means of vertical fastening said shelters to said foundation elements, all in the same sequential order.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention, as well as some preferred embodiments thereof, may be best understood and appreciated from the following detailed description made in conjunction with the drawings in which:

Fig. 1 is a schematic isometric view of a tower mounted on a foundation constructed in accordance with one embodiment of the present invention;

Fig. 2 is a schematic top view of the tower and foundation of Fig. 1;

Fig. 3 is a horizontal cross sectional view of the entire foundation of Fig. 1;

Fig. 4 is a vertical cross sectional view of the entire foundation of Fig. 1,

made through its central vertical axis;

Fig. 5 is another vertical cross sectional view of the entire foundation of Fig. 1, made closer to one of its edges;

Fig. 6 is a side view of a wall of a shelter constructed in accordance with the embodiment illustrated in Figs. 1 to 5, which is designed to abut an adjacent shelter's wall;

Fig. 7 is a cross sectional view of two abutting walls of adjacent shelters constructed in accordance with the embodiment illustrated in Figs. 1 to 6;

Fig. 8 is a local cross-sectional view of two abutting walls of adjacent shelters, illustrating one embodiment of the means for coupling said two abutting walls;

Fig. 9 is a local cross-sectional view of two abutting walls of adjacent shelters, illustrating an alternative embodiment of the means for coupling said two abutting walls;

Fig. 10 is a local cross-sectional view of two abutting walls of adjacent shelters, illustrating two additional alternative embodiments of the means for coupling said two abutting walls, differing very slightly from each other, both contemplating certain advantages over the embodiments illustrated in Figs. 8 and 9;

Fig. 11 is a schematic top view of a foundation constructed in accordance with an alternative embodiment of the present invention, utilizing four shelters, each differing in its shape from all the others;

Fig. 12 is a schematic top view of a foundation constructed in accordance with yet another alternative embodiment of the present invention, utilizing three identical shelters, having an overall circular contour shape and a central vertical shaft of a triangular cross section;

Fig. 13 is a schematic top view of a foundation constructed in accordance with yet another alternative embodiment of the present invention, utilizing four identical shelters, having an overall square contour shape and a central vertical shaft of a square cross section;

Fig. 14 is a schematic top view of a foundation constructed in accordance with yet another alternative embodiment of the present invention, utilizing six

identical shelters, having an overall hexagonal contour shape and a central vertical shaft of a hexagonal cross section;

Fig. 15 is a schematic top view of a foundation constructed in accordance with yet another alternative embodiment of the present invention, utilizing four identical shelters, having an overall square contour shape and no internal vertical shaft at all;

Fig. 16 is a schematic top view of a foundation constructed in accordance with yet another alternative embodiment of the present invention, utilizing three shelters, having an overall rectangular contour shape and no internal vertical shaft as well;

Fig. 17 is a schematic isometric view of a foundation enhancement assembly constructed in accordance with one embodiment of the present invention, which is suitable for enhancing the foundation assembly illustrated in Figs. 1 to 7;

Fig. 18 is a schematic isometric view of one of the four foundation elements forming the a foundation enhancement assembly illustrated in Fig. 17;

Fig. 19 is a schematic top view of the floor of one of the shelters illustrated in Figs. 1 to 7, further adapted so as to be vertically fastened to one of the foundation elements illustrated in Figs. 17 and 18;

Fig. 20 is a local cross-sectional view of two abutting walls of adjacent foundation elements, as well as the two abutting walls of the adjacent shelters supported by said foundation elements, illustrating generally also the means for vertical fastening between the shelters and the foundation elements;

Fig. 21 is an enlarged cross-sectional view of one embodiment of the means for vertical fastening between the shelters and the foundation elements;

Fig. 22 is a series of schematic isometric views of the various steps in one embodiment of the method for constructing the foundation illustrated in Figs. 1 to 7;

Fig. 23 is a series of schematic isometric views of the various steps in one embodiment of the method for constructing the foundation enhancement assembly illustrated in Fig. 17, and on top of it the foundation assembly illustrated in Figs. 1 to 7.

DETAILED DESCRIPTION OF THE INVENTION

The present invention relates to a multi-functional foundation for the tower of a telecommunication site or the like, where the design of a plurality of prefabricated concrete equipment shelters, which are required primarily for the purpose of housing the indoor equipments of a plurality of networks utilizing said tower, is made such that these shelters, after being appropriately positioned and coupled altogether, function also as a suitable foundation for the tower.

As long as the overturning resistance capacity (by structural analysis methods complying with all applicable standards) of the basic foundation assembly described above is found sufficient to stabilize said tower, considering its height and antenna loading – said basic foundation construction, comprising only said coupled shelters, will be applied, and will therefore be placed totally above ground level. Nevertheless, even in said case, the natural soil underneath the foundation (with some excess dimensions there around) down to a certain depth, all subject to engineering choices or constraints, may be replaced with an improved quality soil or base material, such as gravel, crushed stone or sand, which would be properly compacted before the foundation assembly works commence.

When, however, considering the tower's height and antenna loading, the overturning resistance capacity of the basic foundation assembly (described in the previous paragraph) is not sufficient and must be increased – an enhancement assembly of prefabricated foundation elements, which are coupled together in a method similar to that used for coupling together said shelters, and which is placed under said assembly of coupled shelters (and, in most part, under finished ground level) comes into use. The assembly of coupled shelters is mechanically fastened down to said enhancement assembly of prefabricated foundation elements using an adequate fastening method. It would be appreciated by any person skilled in the art, after studying the details of the foundation enhancement as described herein, that the complete enhanced foundation assembly has a considerably increased overturning resistance capacity, compared with the basic foundation assembly described in the previous paragraph.

Thus, one purpose of the present invention is to provide a neat and efficient

solution for the tower foundation and equipment housing in sites where the tower is utilized by a plurality of networks or users, and therefore a plurality of equipment shelters is required. A by-product of the present invention, resulting from the essence of the solution, is that the tower base, located on the shelters' roofs, is not accessible to un-authorized visitors, removing the basic need to surround the site with a fence.

The efficiency of a site utilizing the present invention may be measured, most meaningfully, in terms of its lower cost, compared to the alternative aggregate cost of a plurality of other type shelters, together with the cost of a conventional cast-on-site foundation for the tower, and a fencing all around. Additionally, said efficiency may be measured in terms of the much smaller ground-area required for a multi-user site (i.e. a site used by a plurality of users or networks), a ground area saving which is desirable for both increasing the feasibility of site lease and permitting, and at the same time reducing land lease costs for the long term.

The other purpose of the present invention is to provide a rapidly executable solution for such multi-user Greenfield sites, a property which may be highly appreciated and most welcome when the sites need to be built under fast network roll-out constraints. The entire foundation is made of completely prefabricated components, having transportable dimensions and weights, and except for a possible thin layer of lean (or normal) concrete, which has no structural significance, no other cast-on-site concrete is required in order to form a monolithic and stable foundation for the tower.

The foundation according to the present invention is formed of a plurality of prefabricated concrete components, which may be all identical or, alternatively, may comprise several types. The heart of the invention is the geometrical arrangement of all said components, of which the exact shape and dimensions of each are determined, as well as the methods used to couple together all the components of the foundation, and make them function effectively and safely as if they were one monolithic foundation.

It would be appreciated by persons skilled in the art that a foundation constructed according to the present invention, while being sound for the long term

and therefore suitable to serve as a permanent facility, is also removable if needed, without leaving a non-recoverable trace on site, and therefore may also be suitable for temporary applications. Besides the positive aspect of cost recovery, when the intension is indeed to deploy a short or medium term solution, there is, in some countries, an additional advantage associated with said "removable" feature: a simplified Building Permit procedure.

Referring to Figs. 1 and 2, there are shown respective isometric and plan views of a tower foundation and a tower constructed in accordance with one embodiment of the present invention. As can be seen, a tower 20 is mounted on a foundation 10. Tower 20 can be any possible type of telecommunication tower (or other purpose tower) requiring a sound foundation to sustain its loads and stabilize it against overturning. Tower 20 can be of various conventionally known shapes (i.e. Lattice Tower or Monopole type), heights, or dimensions. The tower illustrated in Figs. 1 and 2 is a Lattice Tower with four legs 22. The bottom ends of legs 22 are provided with base plates 24, which are a commonly used means for providing adequate structural connection between the tower 20 and the foundation 10, as described below. Other possible alternative means for providing said adequate structural connection are also known in the art.

The tower foundation according to the present invention is formed of several prefabricated equipment shelters, preferably at least three shelters, made of reinforced concrete. In the embodiment of the invention illustrated in Figs. 1 and 2, the foundation 10 comprises four identical equipment shelters 12. Each of the equipment shelters 12 in this embodiment is of a substantially rectangular plan contour, and is provided with a door opening 14 on one of its outer walls. The entire foundation assembly 10 is of a substantially square plan contour.

Shelters 12 are arranged such that a polar symmetry exists there between, about a central vertical axis of polar symmetry 1. In the preferred embodiment illustrated in Figs. 1 and 2, tower 20 is also concentric with said central vertical axis of polar symmetry 1.

Every two adjacent shelters 12 are abutting each other, with a substantially vertical surface of contact 50 defined there between. The means for coupling together said every two adjacent shelters 12, as described below, are effected

transversely through said surface of contact 50, or more accurately, through both abutting concrete walls, each located on either side of said surface of contact 50.

It will be appreciated that the equipment shelters made according to the present invention may be all identical in plan shape and dimensions, or all different from each other, or part of them identical and the rest different, all depending on engineering choices or constraints. However, all said equipment shelters must geometrically fit each other such that altogether, when positioned and coupled as designed for that purpose, they form a complete foundation of the designed shape and size. Fig. 11 illustrates an embodiment of the invention where a complete foundation assembly 11 of a substantially square plan contour is made-up by four shelters 15, 16, 17 and 18, where none of said shelters is identical to any of the other shelters.

It will be further appreciated that the contour shape (and size) of the complete foundation assembly made according to the present invention may be of various geometrical shapes, such as substantially triangular, square, hexagonal, circular, etc.

Referring now to Fig. 12, there is shown a substantially circular foundation assembly 31, made-up of three identical equipment shelters 32. Fig. 13 illustrates a substantially square foundation assembly 33, made-up of four identical equipment shelters 34, shaped according to a different embodiment of the present invention than that illustrated in Figs. 1 and 2. Fig. 14 illustrates a substantially hexagonal foundation assembly 35, made-up of six identical equipment shelters 36. In all these cases, when the shelters are all tightly coupled together, they form a monolithic “Raft” type foundation for the tower, that has a substantial overturning resistance capacity attributed to the combination of its dimensions and its aggregate weight.

Referring again to Fig. 2 it can be appreciated that each of the base plates 24 of the tower 20 are fastened down to the roof of the foundation assembly 10 by a tower base anchoring apparatus comprising four elongated vertical threaded elements 40, which are known in the art as Anchor Bolts, and are embedded in the shelters’ concrete casting. It will be appreciated that the resistance capacity of each anchor bolt 40 (against pull-out) is greatest when said anchor bolt 40 is sized

and located such that it is embedded not only in the roof slab of the shelter, but down to a certain depth into the concrete wall of the shelter as well. It is advantageous, therefore, to locate said tower base anchoring apparatus near the perimeter of the shelter's roof, as close as possible to the center-plane of an underlying wall. An illustration of one possible typical shape of anchor bolts 40 can be seen in Fig. 6, and an illustration of the preferred location of tower base anchoring apparatus 40 relative to the wall underneath can be seen in Fig. 7, which also illustrates that such apparatus 40 embedded separately in the castings of two adjacent shelters may be used jointly to receive the base of a single tower leg.

It will be appreciated by persons skilled in the art that the appropriate mechanical fixing of the tower base to the foundation 10 may be achieved also by other anchoring apparatus known in the art, such as embedded steel plates or profiles with appropriate holes for bolting. Nevertheless, the use of anchor bolts has the important advantage of possible adjustment of the tower's verticality after the completion of the foundation's construction. For this reason, the use of anchor bolts 40 is selected herein as part of the preferred embodiment of the present invention.

In the preferred embodiment illustrated in Figs. 1 and 2, the tower base anchoring apparatus is located identically on the roofs of each of shelters 12, so resultantly the entire tower base anchoring apparatus in the complete foundation assembly is characterized by a polar symmetry about said central vertical axis 1, so as to receive tower 20 which, in the preferred embodiment, is concentric with same central vertical axis 1.

It will be appreciated, however, that a foundation constructed according to an alternative embodiment of the present invention, or even the foundation illustrated in Figs. 1 and 2, may be fitted to receive a tower which is eccentric to said central vertical axis 1, i.e. the vertical central axis of the tower may not coincide with said central vertical axis (of the foundation) 1. This is normally not a desired arrangement, but rather the result of some constraints, yet it may be achieved either by providing the tower base anchoring apparatus, during the casting of the shelters, in an un-symmetrical arrangement, or by using only part of

the tower base anchoring apparatus (if made symmetrically as illustrated in Figs 1 and 2), or even through the use of a tower base interface structure which may have a bottom fixing apparatus of a polar symmetry but a top fixing apparatus fitted to the base of the eccentric tower.

Following from all the above, it will be appreciated that each of foundation 10 illustrated in Figs 1 and 2 and foundation 33 illustrated in Fig. 13 is geometrically best fit to receive a concentric lattice tower having four legs, while each of foundation 31 illustrated in Fig. 12 and foundation 35 illustrated in Fig. 14 is best fit to receive a concentric lattice tower having three legs. This, however, is not a mandatory rule: a three legged tower may be fitted to be mounted onto foundation 10 or foundation 33, in a concentric or an eccentric manner, with or without the use of a tower-base interface structure, and the same applies to the possibility of mounting a four legged tower onto any of foundations 31 or 35.

The shelters house indoor electronic equipments, and the tower supports various antennae, which are electronically connected to said equipments. The means for said electronic connection can be any kind of feeder cables or other antenna cables, which must be routed in between said antennae and said indoor equipments. One possible way to route said feeder cables or antenna cables is to penetrate vertically through the shelter's roof slab. This method, however, contemplates a great hazard of rain-water penetration into the shelter through the cables' penetration detail, in case that detail is not sealed watertight with ultimate perfection, and is certainly not the common method. The common and preferable method is to penetrate into the shelter substantially horizontally, through one of its perimeter walls, which are not abutting adjacent shelters. Yet the use of an outwardly facing perimeter wall for cable penetration has also several clear disadvantages, the most important of which are the vulnerability of the cables and the greater lengths of the cable routes.

Hence, it becomes desirable to have an internal vertical shaft, which would facilitate a substantially horizontal cable penetration into each of the shelters (i.e. through a wall) while ensuring minimal route lengths for the cables as well as minimal degree of vulnerability.

Referring again to Figs. 1 and 2, it can be seen that the four identical

shelters 12 encircle a central vertical shaft 60, which is also concentric with said central vertical axis (of the foundation) 1. In Fig. 4, said central vertical shaft 60 can be seen in a vertical cross-sectional view.

Referring now to Fig. 11, it can be seen that shaft 61 is encircled by the four different shape shelters 15, 16, 17 and 18, such that shaft 61, in this embodiment, is eccentric relative to the center point of the entire square foundation 11. In Fig. 12, the three identical shelters 32 encircle a concentric triangular shaft 62, in Fig. 13, the four identical shelters 34 encircle a concentric square shaft 63, and in Fig. 14, the six identical shelters 36 encircle concentric hexagonal shaft 64.

Nevertheless, the utilization of a central or internal vertical shaft is only a preferred option, which may be disregarded. Fig. 15 illustrates a foundation assembly 37 made-up by four identical square shelters 38, without any internal shaft. Similarly, Fig. 16 illustrates a foundation assembly 39 of a rectangular contour, made-up by three rectangular shelters of two different types: 238 (two units) and 239, this embodiment again has no internal shaft. In these last two cases, and despite the disadvantages described above, cable penetration would take place either through the shelters' roofs or through their exterior walls.

In order to complete a neat penetration of the antenna cables, as well as other possible utility cables or pipes, through the walls of the shelters, it would be a good practice to prepare the penetration openings in the shelters' casting. These openings may be of any desired quantity, shapes, sizes and locations, all subject to specific engineering considerations. Most preferably, said openings will be fitted to receive certain types of cable penetration sealing devices, available as off-the-shelf purchase items.

Referring now to Fig. 3, cable openings 66 can be seen in the wall sections separating between each of the shelters 12 and the central shaft 60. Same openings 66 can also be seen in the cross-sectional view of Fig. 4, in locations which are typical but not mandatory.

Referring now to Fig. 5, there can be seen a preferred embodiment of the means 70 for coupling together every two adjacent shelters, which are effected transversely through the shelters' wall sections that abut each other. In general terms, said means for coupling together every two adjacent shelters comprise a

single or a plurality of substantially horizontal bores, passing substantially transversely through both said abutting walls, such that substantial bore alignment exists there between in the final planned position, as well as a matching number of substantially horizontal elongated connecting members which are inserted through said bores and then tightened.

The most simplified embodiment of the means for coupling together every two adjacent shelters is shown in Fig. 8, which is a local cross-sectional view made through said means for coupling two adjacent shelters, or more specifically: coupling their two abutting walls 42. A transverse bore 72 is provided in each of the walls 42, such that the axes of both bores 72 substantially coincide when the shelters are brought to their final positions. Then an elongated connecting member comprising, in this embodiment, a bolt 74 of appropriate size and length, is inserted through the aligned bores 72, then equipped with a matching nut 75 and tightened. In most practical applications, the use of plate-washers 76, at both ends, is a recommended practice.

Fig. 9 illustrates another embodiment of the means for coupling together two adjacent shelters. In this embodiment, bores 82 in abutting walls 44 are made by using lining sleeves 83, which may be of either metal or plastic material, in the concrete casting of said walls 44. In this embodiment, the elongated connecting member comprises a rod 84, which may be threaded all along, or alternatively (as shown) threaded in same direction only along both its ends. Each end of the elongated connecting member 84 includes, in this embodiment, a respective end tightening assembly, comprising two nuts 85 (first nut for tightening and second nut for locking), as well as preferred plate-washers 86.

It will be appreciated that both the embodiment illustrated in Fig. 8 and that illustrated in Fig. 9 may be applicable when the projection of said elongated connecting members from the wall surfaces is tolerable, from the user's point of view, or alternatively, when these inwardly projecting elements end up being covered by any type of internal wall lining, such as gypsum-board or the like.

Nevertheless, a much more favorable solution is one in which no part of the means for coupling together two adjacent shelters would project inwards from the shelter's wall surface. To make said more favorable solution feasible, said end

tightening assemblies of the elongated connecting members must be concealed within large enough recesses in the abutting concrete walls.

Fig. 10 illustrates two slightly different embodiments of said more favorable solution, which include recesses: on the right hand side of Fig. 10, recess 90 is formed by metal liner 92 and plate 97, which is substantially larger than the cross-section of the recess 90. Plate 97 includes a central hole which is substantially concentric with bore 88, and allows the passage of elongated connecting member 94 there through. Plate 97 has two roles: first role - to provide a support surface against which the end tightening assembly of said elongated connecting member abuts when tightened, and second role, owed to its increased dimensions – to distribute the concentrated load created by tightening the elongated connecting member 94 over a larger area of the concrete wall 46.

The left hand side of Fig. 10 illustrates a slightly different embodiment: in this embodiment recess 91 is no different than recess 90 described above, and liner 93 is respectively no different than liner 92. However the vertical plate 98 is substantially the size of the cross section of recess 91. In this embodiment, bent bars 99 which are welded to liner 93, thereby connected also to plate 98, take the role of distributing the concentrated load created by tightening the elongated connecting member 94 over a larger area of the concrete wall 47.

Both embodiments illustrated in Fig. 10 indicate the use of lining sleeves 89, which would be welded to the back side of plate 98 (or respectively plate 97) for the creation of bores 88. Indeed, the use of a liner for the creation of the recess makes the use of the “liner concept” throughout the wall’s thickness a preferred practice. Nevertheless, it will be appreciated that the use of a liner only over part of the wall’s thickness, for example only to create the recess, while the bore would have no lining sleeve, is also feasible.

Under various service loads, to which the tower and the foundation may be subjected, shear stresses may develop within the substantially vertical surface of contact defined between any two adjacent shelters (surface 50 in the embodiment illustrated in Figs. 1, 2 and 3). The possible consequence of said shear stresses, if they exceed certain resistance values, might be a slight relative vertical or lateral movement between the respective two adjacent shelters, a very undesirable

consequence that might adversely effect the overall functionality of the foundation.

If the faces in contact of any two abutting walls would be totally planar surfaces, then the resistance of the system to said relative movement resulting from shear stresses depends only upon the friction developed in between said two surfaces in contact, which by itself depends upon two factors: the surfaces' friction factor, governed by the material and by the surfaces' roughness, and the normal contact pressure there between, which is governed by the extent of tightening the means for coupling the shelters.

It will be appreciated by persons skilled in the art that, in some realistic loading scenarios, said friction might not provide sufficient resistance to said relative movement resulting from shear stresses, and therefore said resistance must be increased.

The optional apparatus provided in the present invention, for increasing said resistance to relative movement resulting from shear stresses, is the provision of a bulge or a plurality of bulges, of any desired shape and size, in said substantially vertical surface of contact defined between any two adjacent shelters. In practical terms, each said bulge is defined by a protrusion formed on one of said two abutting walls, and a socket of a matching shape, size and location, formed in the second of said two abutting walls, the protrusions and sockets are designed so as to interlock with each other, and thereby prevent any possible relative movement there between.

Referring now to Fig. 5, the embodiment illustrated herein includes, in each of the four contact surfaces 50, four round conical bulges 52. In practical terms, as can bee seen in Fig. 7, each of said bulges 52 is formed by a round conical protrusion 54 on wall 48, and a socket 56 of matching shape, size and location, in the abutting wall 49.

It will be appreciated that during the various handling operations that every shelter must be subjected to, such as loading for transportation, off-loading on site and bringing to final position with the use of a crane on site, said protrusions may become vulnerable to damage due to mechanical impact. One possible method for protecting said protrusions, and optionally also said sockets, against damages resulting from mechanical impacts is to provide over any desired part of their

surfaces liners of material more durable than the concrete, such as steel. Said liners will be placed, obviously, prior to casting the concrete of the respective walls.

Another possible practical problem may be caused by penetration of a hard foreign particle, such as a small stone, to the space in between any two abutting walls during assembly operations on site. Resultantly, when the shelters are pulled as close as possible to each other, through maximal tightening of the means for coupling them together, even to a degree that said foreign particle is crushed, it might still prevent the final desired contact between the surfaces of said walls, and consequently said protrusions and matching sockets would not reach full interlocking contact, and the benefit of applying said protrusions and sockets would be derogated.

One feasible solution, making the system substantially immune to the potential problem described above, is designing the abutting wall surfaces of the shelters geometrically such that, in the process of assembling any two adjacent shelters, when said protrusions and matching sockets fully interlock, and resultantly the respective adjacent shelters may not be brought any closer to each other, a relatively thin clearance remains in between the substantially planar parts of the two abutting wall surfaces. By any mechanical consideration, and as long as said protrusions cover a certain minimal percentage of the abutting wall's area, said thin clearances may be left free and the foundation would nevertheless function properly for the long term. For some non-structural considerations, however, it would be preferable to fill the said clearances with cement based grout, or with any other suitable material of no structural role, after final tightening of the means for coupling the shelters.

The precise detailed method of constructing a foundation made in accordance with the present invention may vary from one specific application to the other, a variation that depends, primarily, upon the specific soil conditions, as well as the specific topographical conditions existing on site before the commencement of the construction works.

For example, if the tower is to be located on a site where a sound rock extends up to the ground surface level, then the load bearing capacity of the natural base in the surface level would not constitute any problem, and the only

measure that must be applied is the provision of a well-leveled base surface to receive the foundations. This would normally be achieved by flattening the rock surface in the site area to the best possible extent, and then applying a minimal thickness layer of lean (or normal) concrete, which would be proficiently leveled smooth. The use of a granular base layer instead of the concrete is also an option, but then additional measures must be taken to reassure that any part of said granular material might not be washed away by surface running rain water.

If, however, the tower is to be located on normal soil, then the issue of the natural soil's load bearing capacity, as well as other properties of said natural soil, in the various depths, must be carefully examined, by a common practice of soil boring and sampling, and analyzed by an expert, who would establish the recommended measures required to provide an adequate load-bearing surface for the foundation at substantially the ground surface level.

In the common case, said recommended measures would include the excavation and removal of a low quality natural top-soil layer, the exact thickness of which would depend on the specific site conditions, and backfilling with an imported, improved quality soil or base material, such as gravel, crushed stone or sand. Then, on top of the well leveled backfilled base the shelters may be directly placed, or a geo-textile sheet may be placed between the two, or by the most preferable alternative practice, a thin layer of lean (or normal) concrete may be applied and proficiently leveled smooth to serve as best quality support surface for placement of the prefabricated shelters.

From this point and on, the method for assembling the foundation would be substantially uniform in all cases: The shelters are placed, with the use of a sufficient capacity crane, on said prepared base one by one, in a sequential order, so that (with the exception of the first shelter) as soon as each shelter is brought into its final position, relative to the preceding shelter, it is coupled to said preceding shelter and said coupling means are tightened before the assembly process proceeds. Obviously, some of the shelters, in most embodiments the last shelter, must be fitted simultaneously to a plurality of preceding shelters, as well as be coupled to them all at the same time.

Fig. 22 illustrates the preferred common embodiment of the method for

constructing the foundation embodiment illustrated in Figs. 1, 2 and 3:

In Step (a) the site area is excavated down to a depth of natural soil with appropriate load bearing capacity;

In Step (b) an improved replacement base material of appropriate quality is backfilled and properly compacted in thin layers;

In Step (c) a thin layer of lean (or normal) concrete is cast and proficiently leveled smooth. In the illustrated embodiment, a cavity is left in the center of said concrete layer, to allow free drainage of water from the central vertical shaft.

In Step (d) the first prefabricated shelter is brought to its designated final position;

In Step (e) the second prefabricated shelter is brought to its final position relative to the first shelter, and then the means for coupling these two shelters are applied and well tightened;

In Step (f) the third prefabricated shelter is brought to its final position relative to the second shelter, and then the means for coupling these two shelters are applied and well tightened;

In Step (g) the fourth and last prefabricated shelter is brought to its final position relative to both the first and the third shelters, and then the means for coupling the fourth shelter with both the first and the third shelters are applied and well tightened. At this point the foundation construction is substantially complete, and it is ready to receive the tower onto it.

Everything described in detailed reference to the drawings up to this point relates to the basic foundation assembly, comprising only the coupled shelters, which is applicable as long as the overturning resistance capacity of said basic assembly is sufficient to stabilize the tower, considering its height and wind-drag loads.

When a larger tower is required, and consequently a foundation with increased overturning resistance capacity must be applied in order to safely stabilize such tower, an additional foundation enhancement assembly would come into use. The foundation enhancement assembly is placed under said basic assembly of shelters, and it comprises a plurality of prefabricated concrete foundation elements, all having uniform height, shaped as boxes with open tops,

arranged on site with abutting walls and coupled altogether using similar means to those used to couple the shelters altogether.

Additionally, another set of vertical means of fastening the assembly of shelters down to the assembly of foundation elements is provided in the shelters' floors and in the foundation elements' tops.

In a preferred embodiment of the foundation enhancement assembly, the floor of the assembly is projecting horizontally outwards from its perimeter walls, all around the perimeter or along any part thereof, so as to increase the contact area between the bottom surface of the foundation and the underlying supporting surface.

Fig. 17 illustrates a preferred embodiment of a foundation enhancement assembly 100, suitable to be used in conjunction with the foundation embodiment illustrated in Figs. 1 to 3. The assembly comprises four foundation elements 102, shaped as rectangular boxes with open tops, and arranged such that each individual foundation element 102 underlies an individual shelter 12. The foundation elements 102 abut each other, and are coupled altogether using means of transverse coupling 120, which may be similar to the means 70 used for transverse coupling of the shelters 12. It will be noted further that each foundation element 102 has an outwardly projecting floor slab 112, as described above, as well as a capacity 106 to be filled with any preferred type of soil material, so as to increase the mass of the foundation.

Referring now to Fig. 18, it can be seen that each foundation element 102 also includes, in its walls that abut adjacent foundation elements, protrusions 116 as well as recesses 118, which are designed to fulfill the same role as that of protrusions 54 and matching recesses 56 in the walls of shelters 12.

Bores 122, forming part of the means of transverse coupling the foundation elements 120, may also be seen in Fig. 18.

Additionally, on the top surfaces of the walls of foundation element 102, there can be seen, in Fig. 18, the vertical inserts 132, which form part of the means for vertical fastening the shelters 12 down to foundation elements 102.

The entire means for vertical fastening the shelters 12 down to foundation elements 102 may be better understood from Figs. 19, 20 and 21.

Fig. 19 illustrates, in a plan view, a typical preferred embodiment showing the locations of the parts of said means for vertical fastening 140, which are embedded near the perimeter of the floor of shelter 12.

Fig. 20 is a cross-sectional view of two abutting walls of shelters 12 placed on top of two abutting foundation elements 102 which shows, amongst others, an entire assembled embodiment of said means for vertical fastening the shelters 12 down to foundation elements 102. Fig. 21 is an enlargement of said assembled embodiment.

It can be seen, in Fig. 21, that said means for vertical fastening comprises an internally threaded metal insert 132, which is a readily available purchase item, available in various sizes, types and brands, commonly in use in the prefabricated concrete industry. Insert 132 is entirely embedded in the wall of foundation element 102, so that it does not project at all from said wall's top surface, and is well anchored in said wall's concrete owing to anchoring element 134 which, in some embodiments, may be a bent steel bar laced through a hole in the bottom of insert 132.

It can be also seen in Fig. 21, that said means for vertical fastening further comprises a vertical bore 144 passing through the floor of shelter 12. If the user can accept the projection of bolt heads upwards from the shelter's floor, bore 144 may be a simple one, going with a uniform cross-section throughout the floor's thickness, either with or without a lining sleeve 145.

Yet it is more likely, that such a projection of any fastening element from the shelter's floor may not be acceptable by the users. In that case, bores 144 must include recesses 142, which may be similar in shape and size to recesses 90 or 91 in the walls of shelters 12, or different there from, yet the role they fulfill is exactly the same. Comparing the embodiment shown in Fig. 21 to the wall recess embodiments shown in Fig. 10, recess liner 143 has the same role as recess liners 92 or 93, horizontal plate 146 has the same role as vertical plate 98 and bent bars 148 have the same role as bent bars 99.

In the embodiment shown in Fig. 21, the vertical fastening member 150 is a normal bolt, sized to match the threads of insert 132, and the required length. Yet in an alternative embodiment, said vertical fastening member may comprise a

threaded rod, with an end tightening assembly at its top resembling those illustrated in Fig. 10.

It would be clear to any person skilled in the art that the incorporation of the foundation enhancement assembly will also effects the method of constructing the foundation. In addition to the need to prepare before hand a greater number of different prefabricated components, the sequence of construction stages on site is also slightly effected.

Fig. 23 illustrates a preferred embodiment of the method for constructing the foundation enhancement assembly illustrated in Figs. 17 to 21, together with the foundation illustrated in Figs. 1 to 3:

In Step (a) the site area is excavated down to a depth substantially equal to the height of the foundation enhancement assembly, and in a sufficient area therefore, and the bottom of the excavation is carefully leveled and compacted;

In Step (b) the first prefabricated foundation element is brought to its designated final position;

In Step (c) the second prefabricated foundation element is brought to its final position relative to the first foundation element, and then the means for coupling these two foundation elements are applied and well tightened;

In Step (d) the third prefabricated foundation element is brought to its final position relative to the second foundation element, and then the means for coupling these two foundation elements are applied and well tightened;

In Step (e) the fourth and last prefabricated foundation element is brought to its final position relative to both the first and the third foundation elements, and then the means for coupling the fourth foundation element with both the first and the third foundation elements are applied and well tightened;

In Step (f) the excavation all around the foundation enhancement assembly is backfilled and compacted, preferably in relatively thin layers;

In Step (g) the capacities of all the foundation elements, as well as the cavity encircled thereby, are filled up with a selected soil material or a granular material;

Step (h) represents the same further accomplishment as steps (d) through (g) in Fig. 22, with the only difference that in this case special care must be

exercised when placing the first shelter, to the alignment of the vertical means of fastening it down to the underlying foundation element, so as to ensure that consequently all following shelters would so align as well. Additionally, said means for vertical fastening are effected and tightened in each shelter as soon as it is finally positioned, and before placement of any further shelters follow.

When step (h) is completed, the foundation is ready to receive the respective tower on its roof.